Climate Impacts on Reservoir Rule Curves

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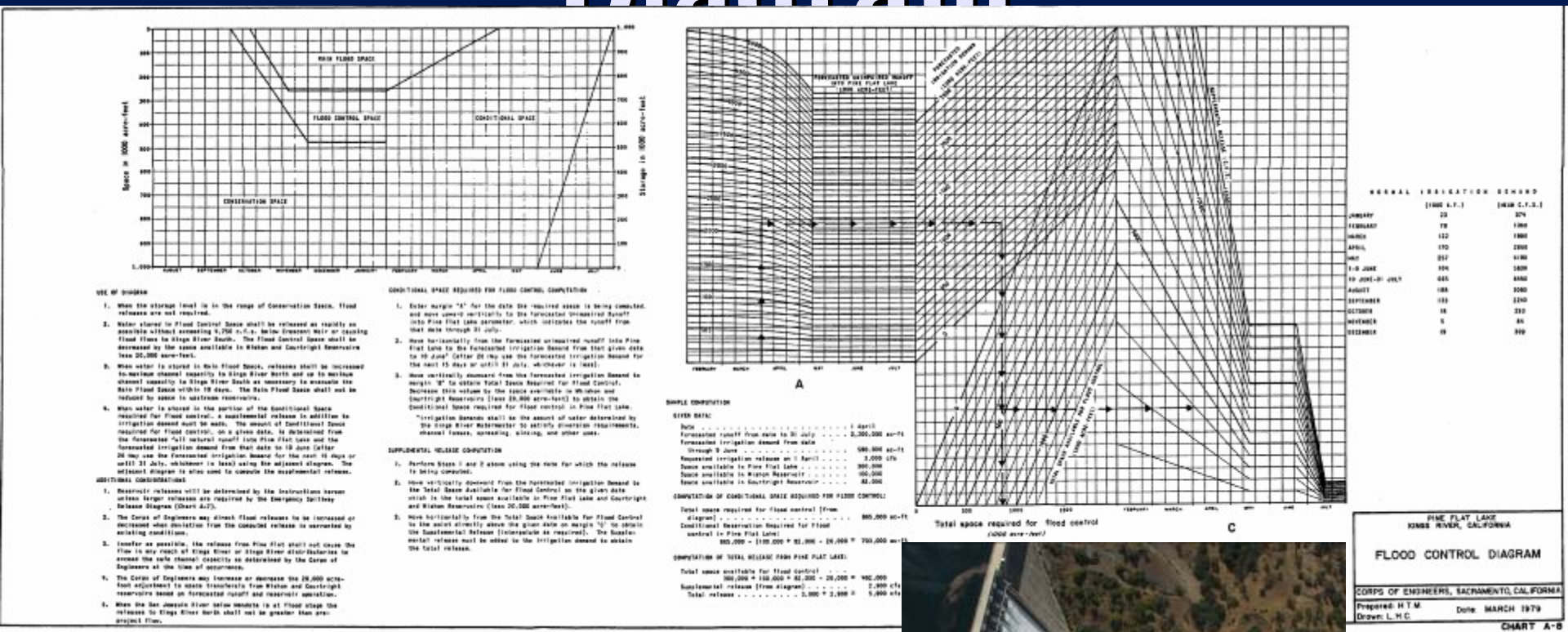
Why I did this?

33 CFR 208.11(10)

Revisions. The water control plan
and all associated documents will be
revised by the Corps of Engineers as
necessary, to reflect changed
conditions
that come to bear upon flood control
and navigation, e.g., reallocation
of reservoir storage space due to
sedimentation
or transfer of storage space
to a neighboring project.

Pine Flat Flood Control Diagram



Typical snowmelt influenced rule

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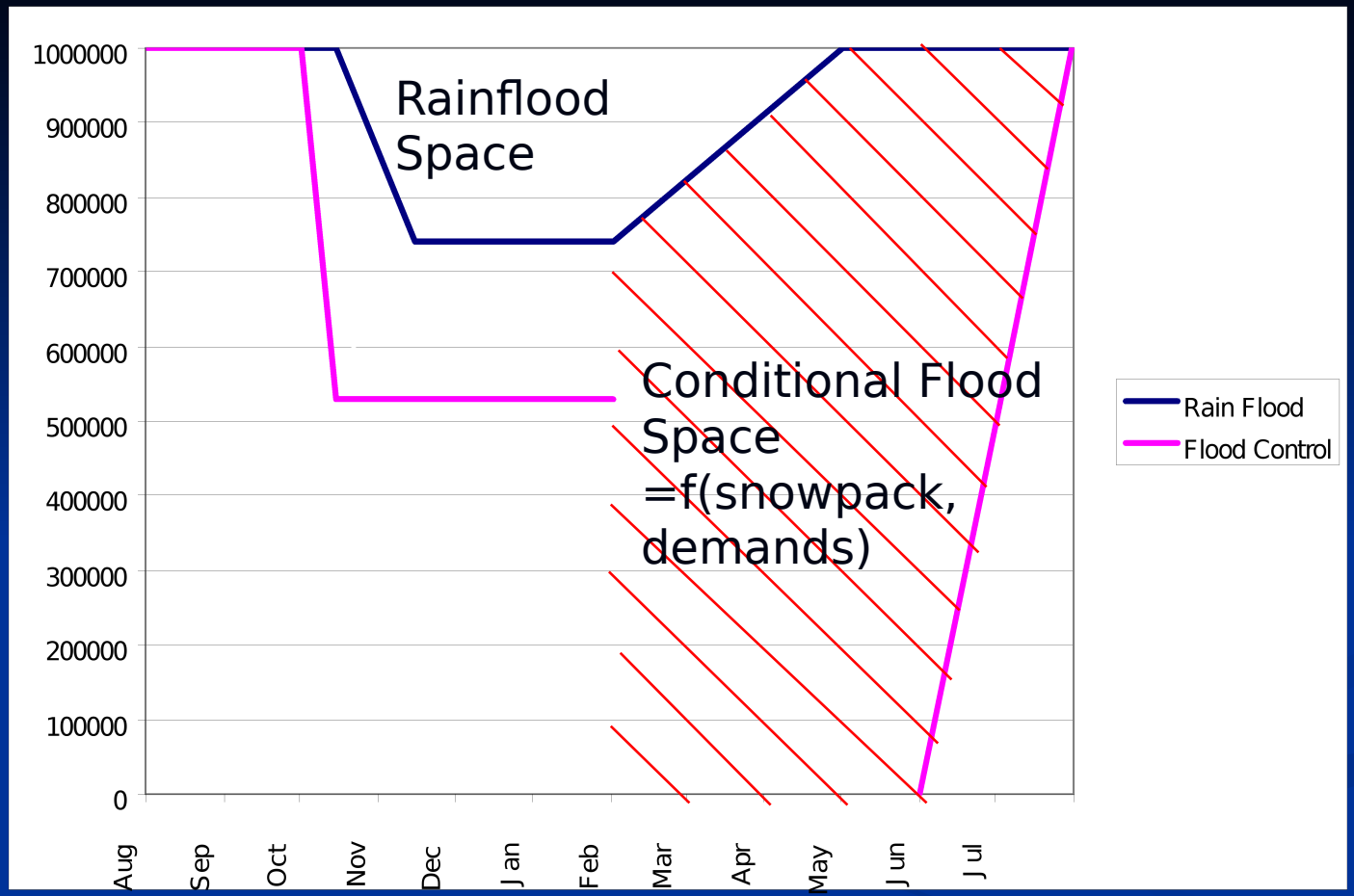
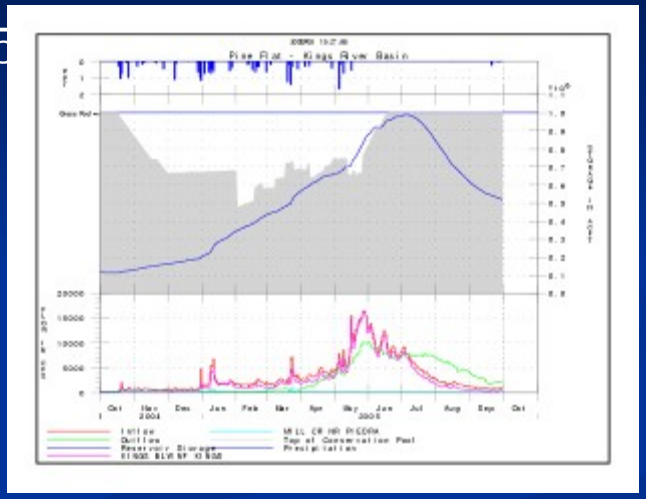


- Developed from historical record (look-back)
- Conditional space dependent on B-120, irrigati
- Operation based on observed data (rainfall, sn

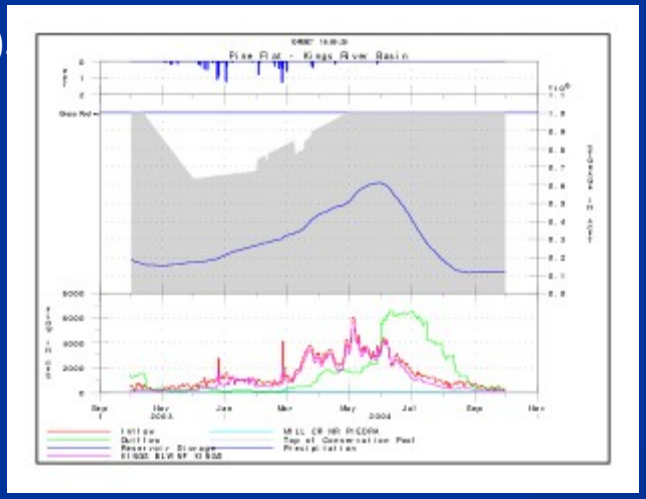
Pine Flat Operations

WY 200

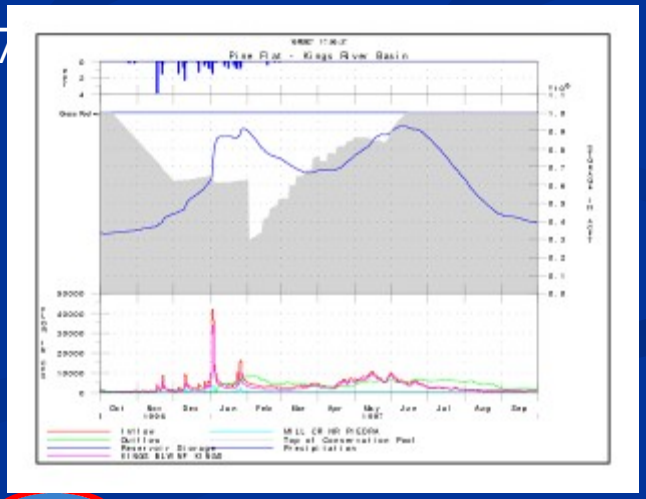
WY 2005



WY 200



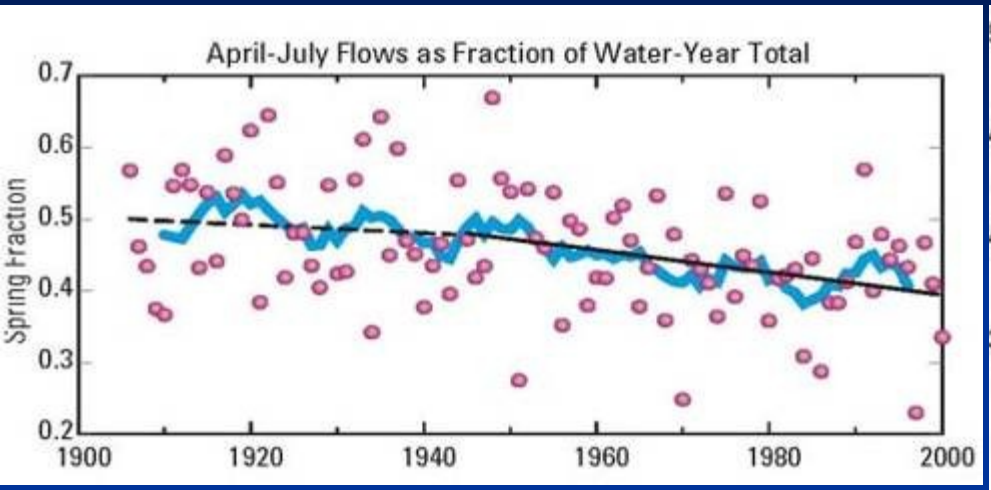
WY 1997



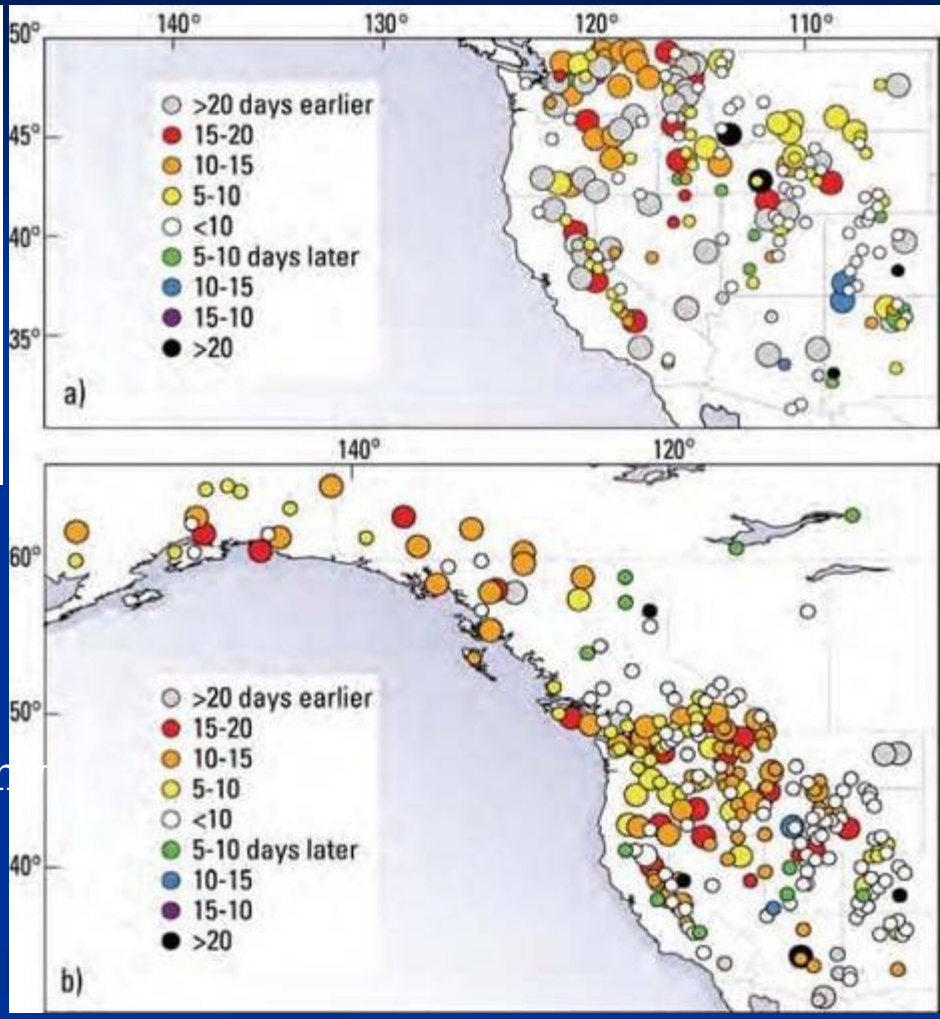
Potential Flood Implications

- Literature suggests
  - Warmer regime, about the same annual precipitation
  - Smaller snowpack, earlier melt, flow shift
  - Greater storm variability/intensity
- Implications?
  - Need more rainflood space?
  - Allow earlier fill?

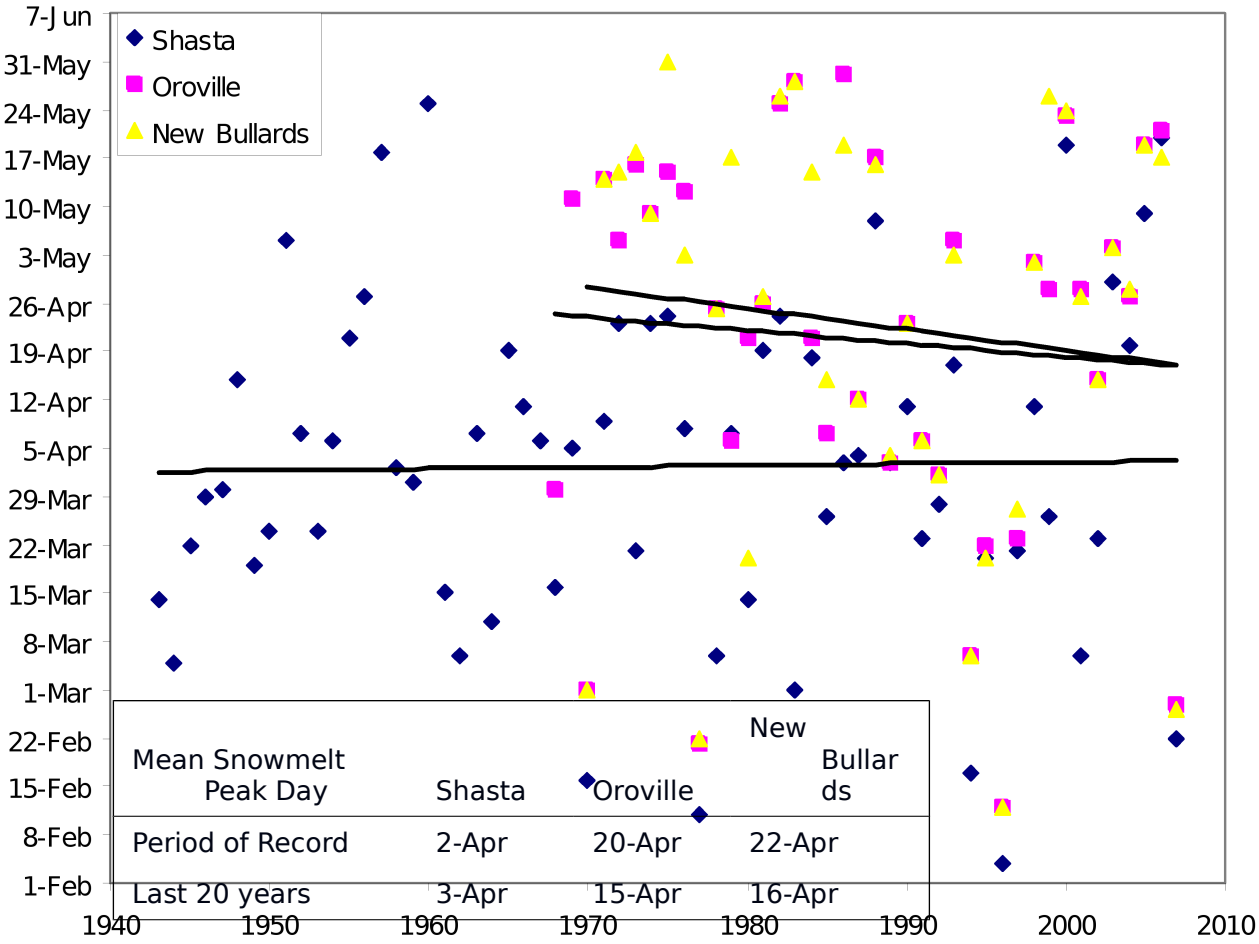
Snowmelt Trends



USGS Fact Sheet 2005-3018
Michael Dettinger
U.S. Geological Survey
Scripps Institution of Oceanograph

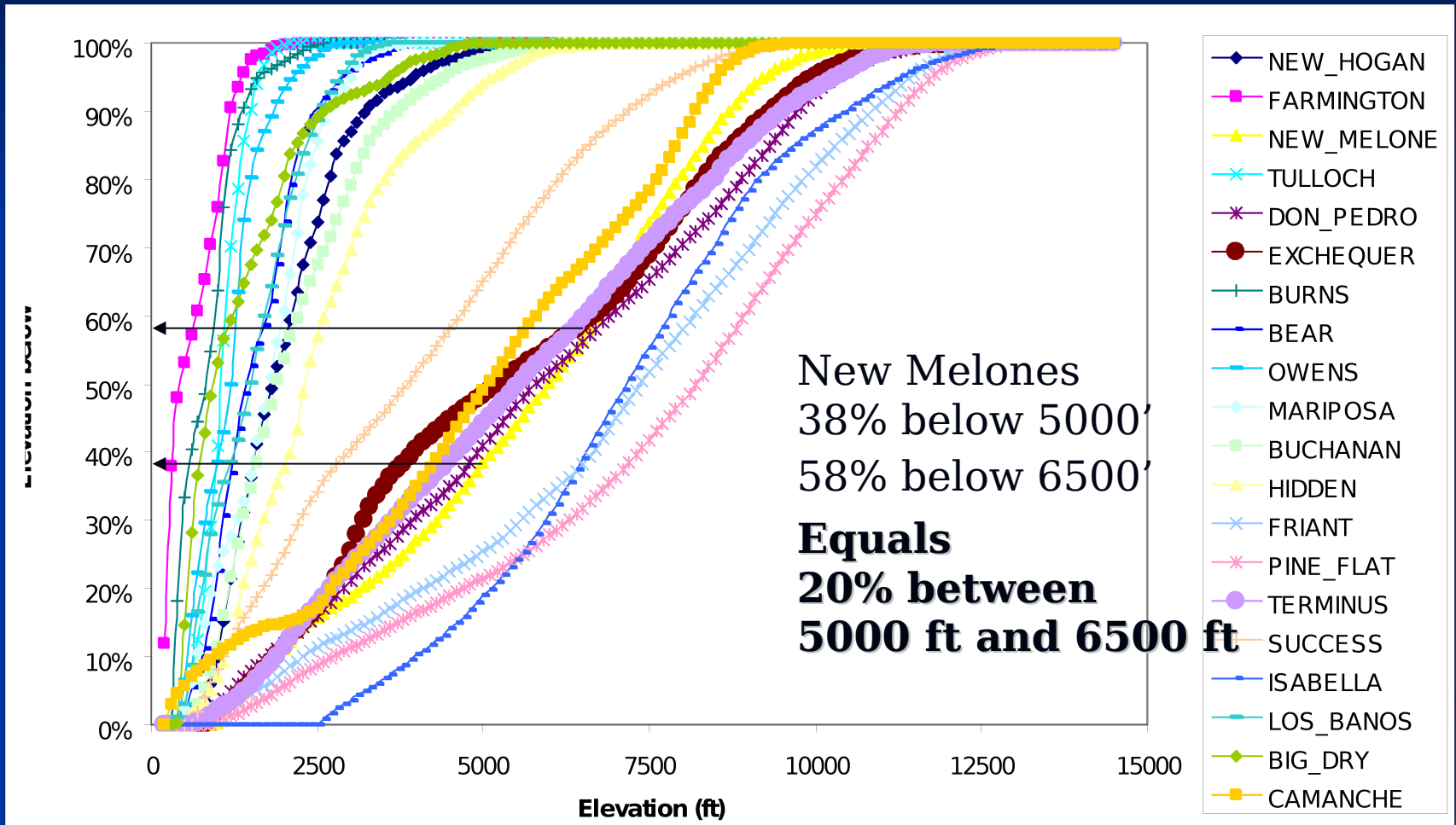


Mean Snowmelt Peak
Full Natural Flows



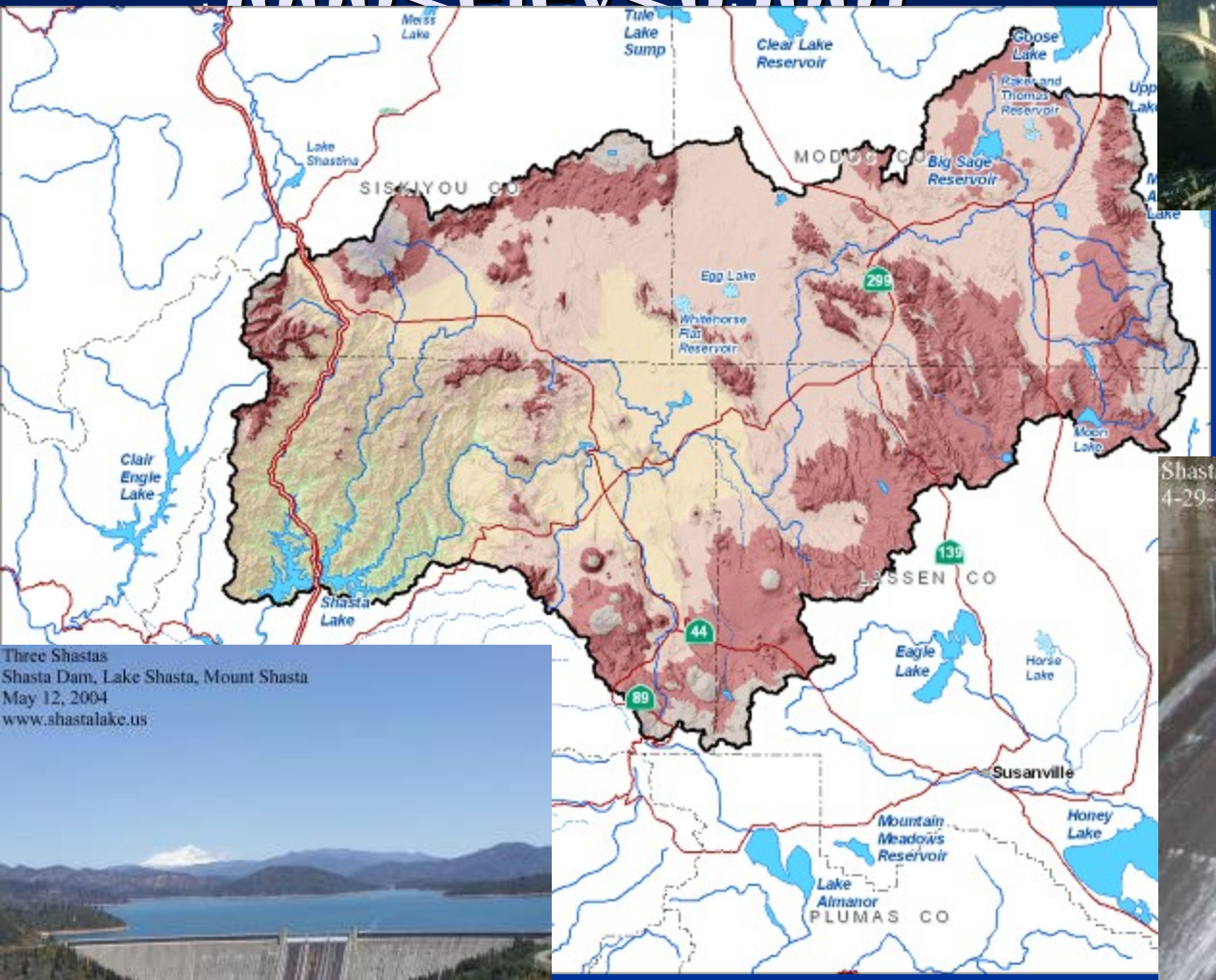
Mean Snowmelt Peak Day	Shasta	Oroville	New Bullards
Period of Record	2-Apr	20-Apr	22-Apr
Last 20 years	3-Apr	15-Apr	16-Apr

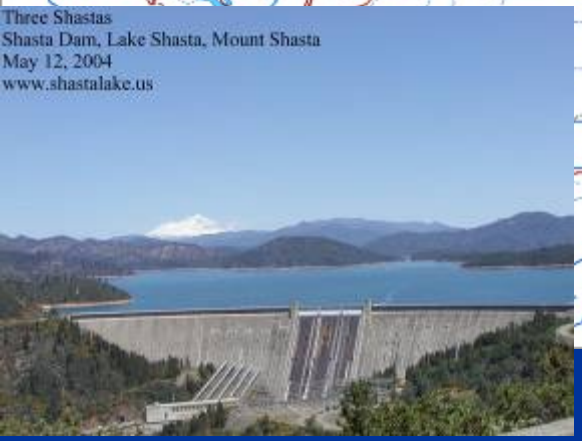
San Joaquin Reservoirs Elevation Percentages



Shasta

(purple = 5000<elev<6500)





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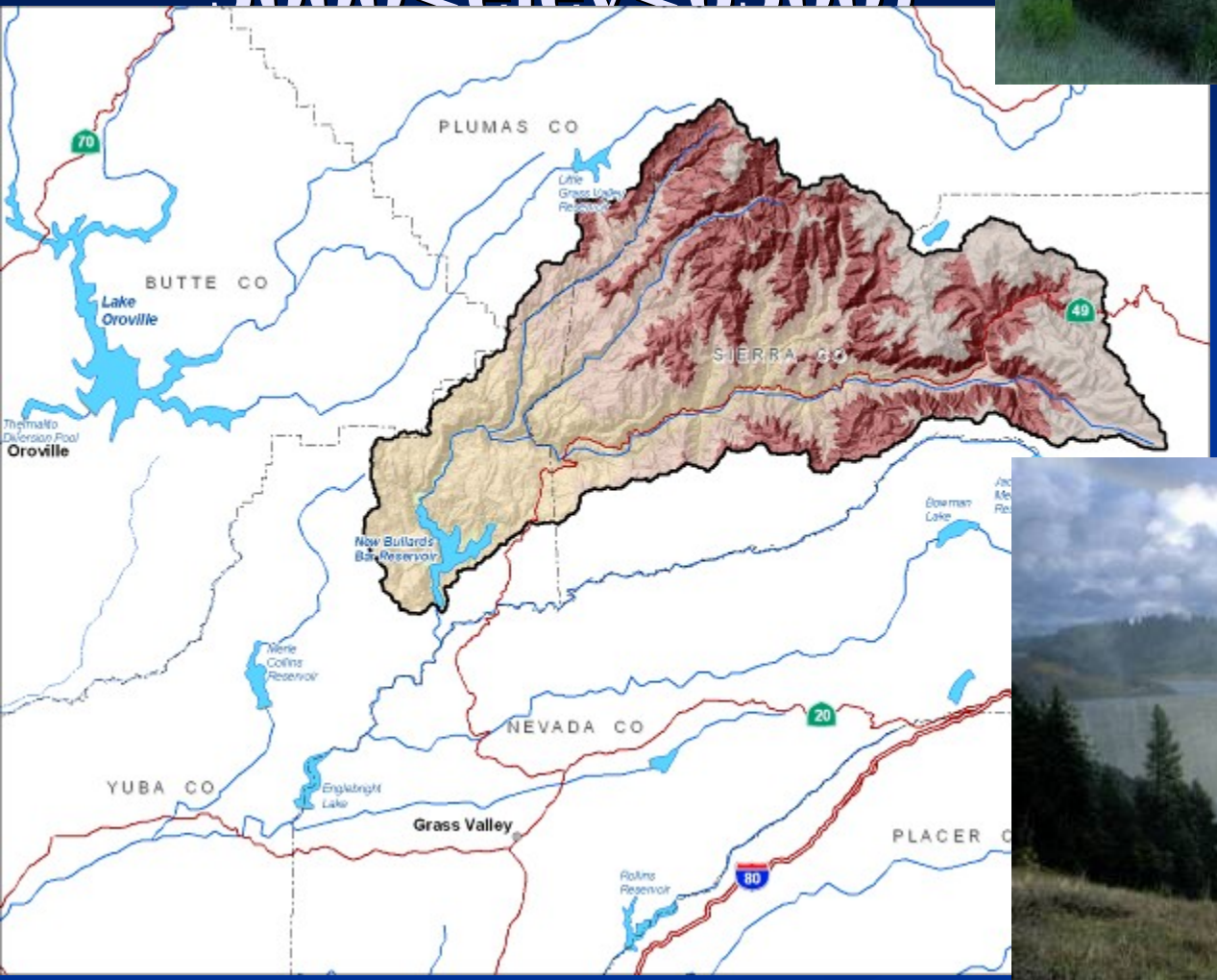
New Bullards

(purple = 5000<elev<6500)



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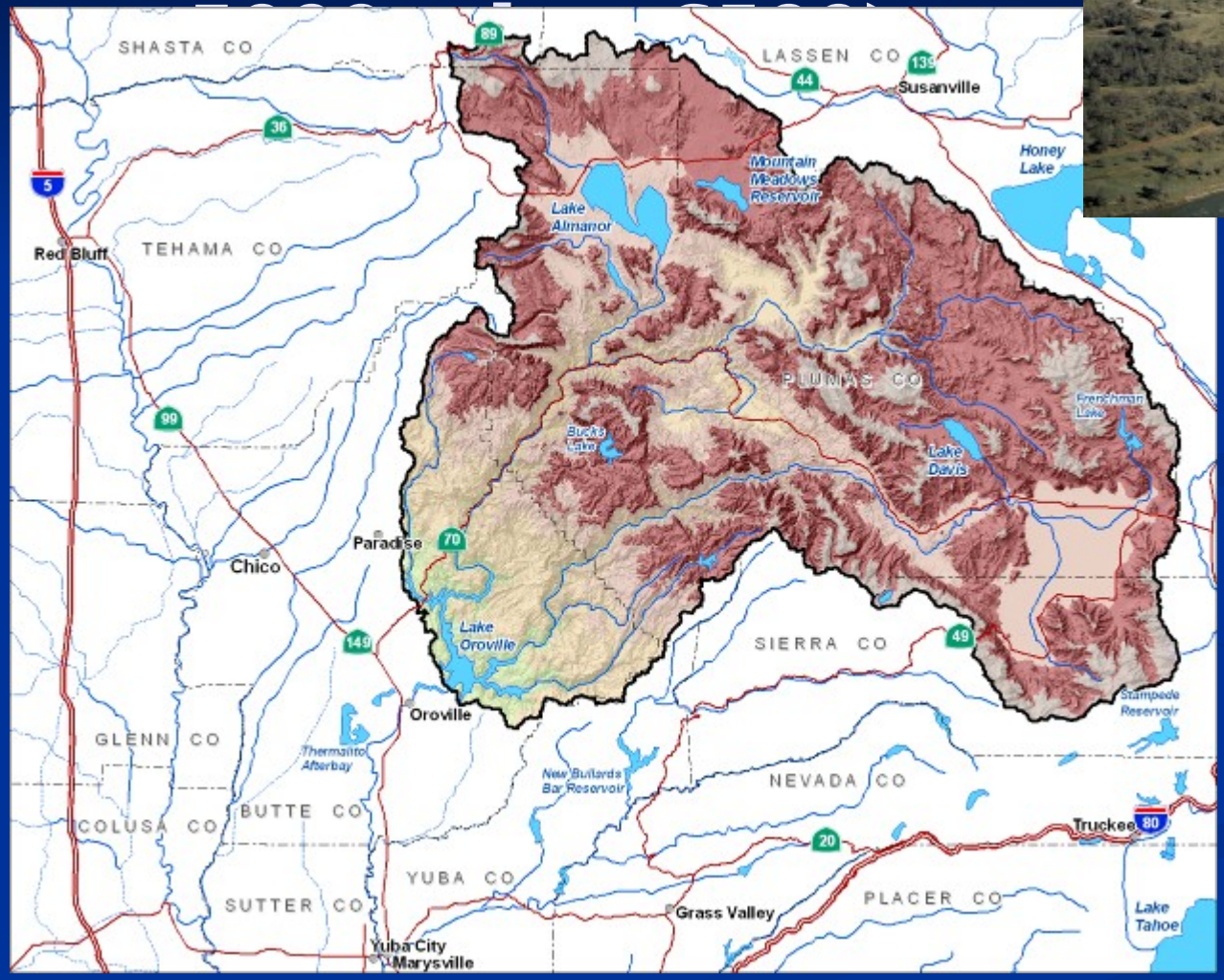
Oroville Drainage

(purple =



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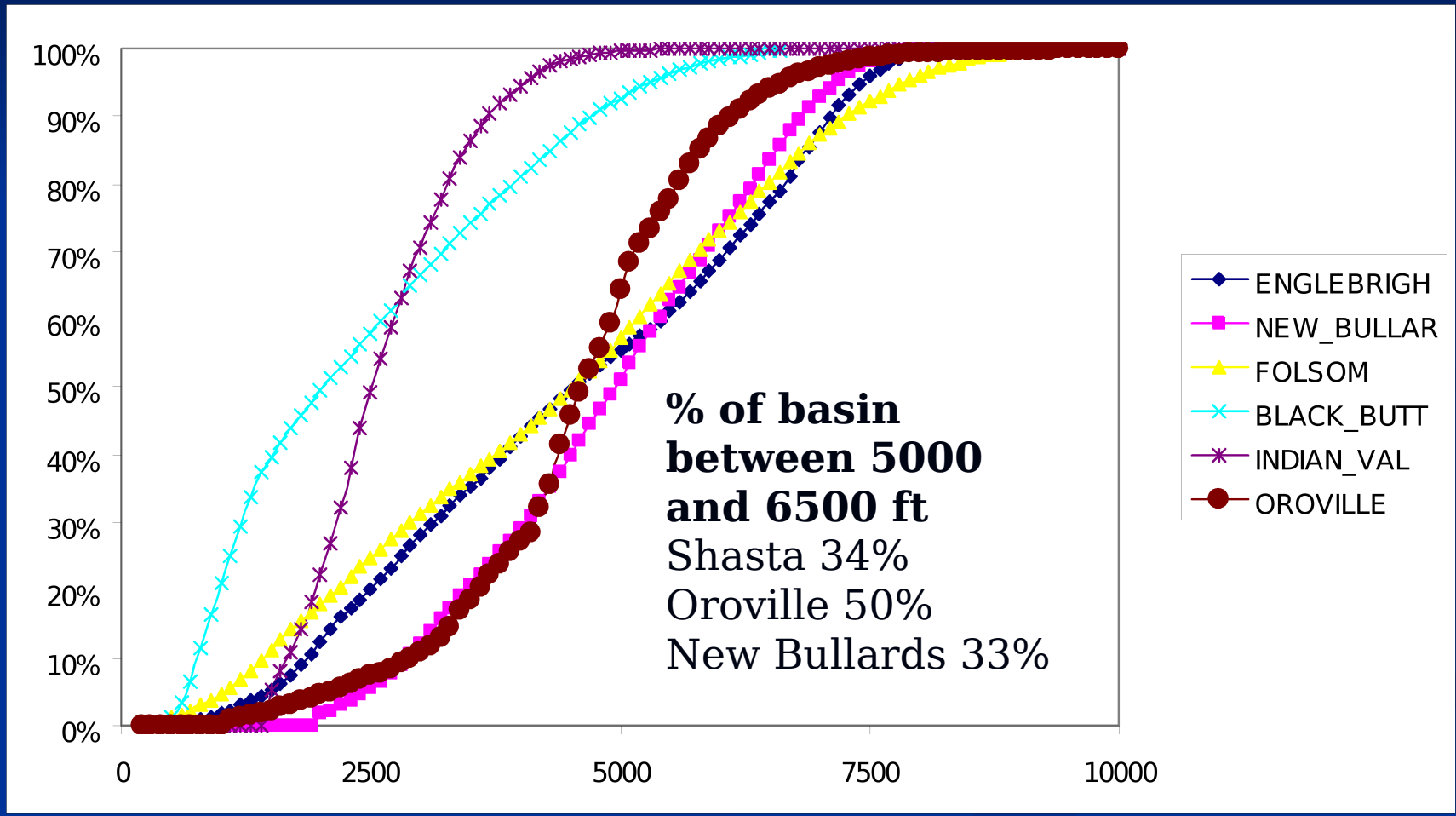
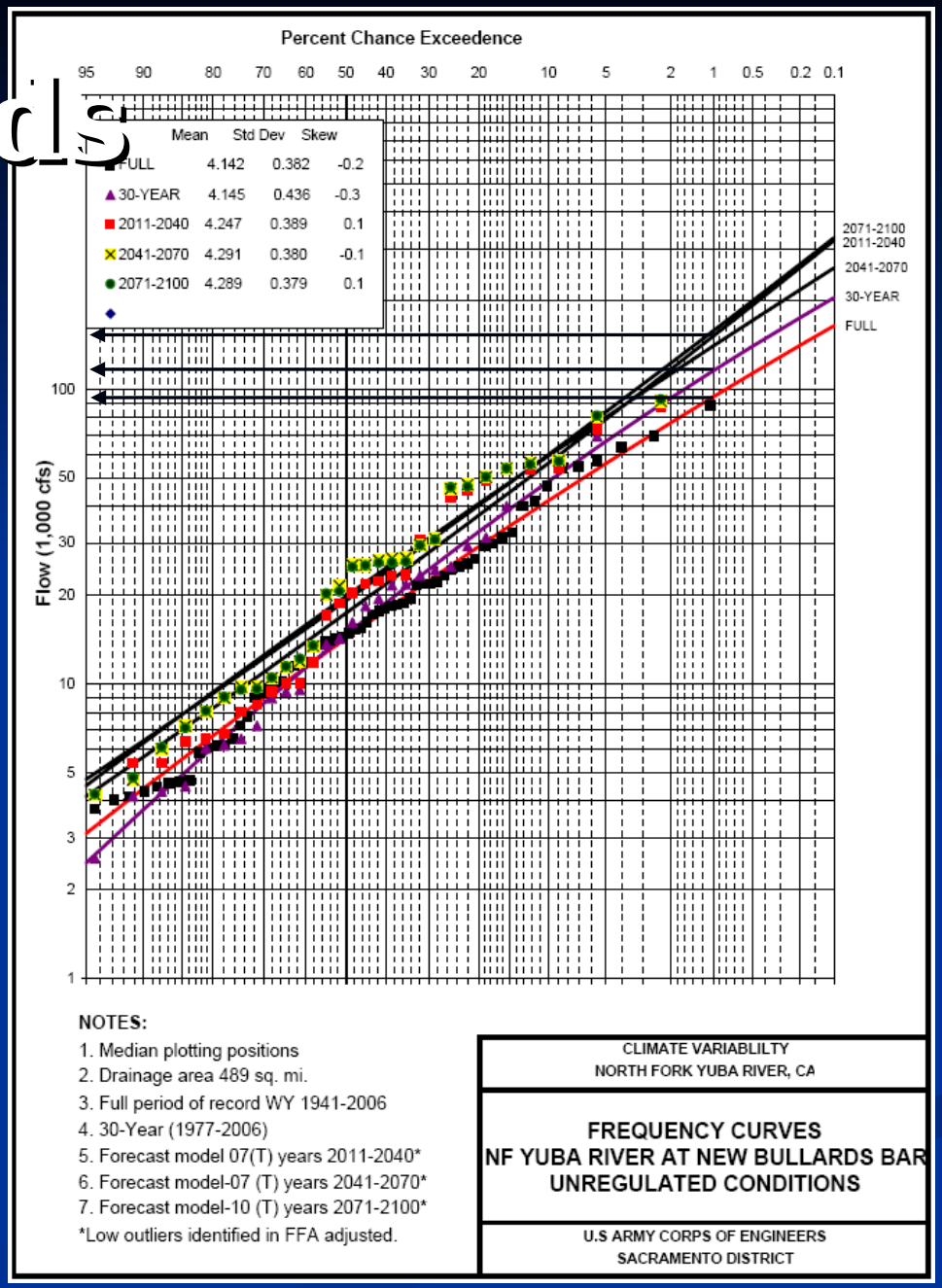
Sacramento Reservoir Elevation Percentages



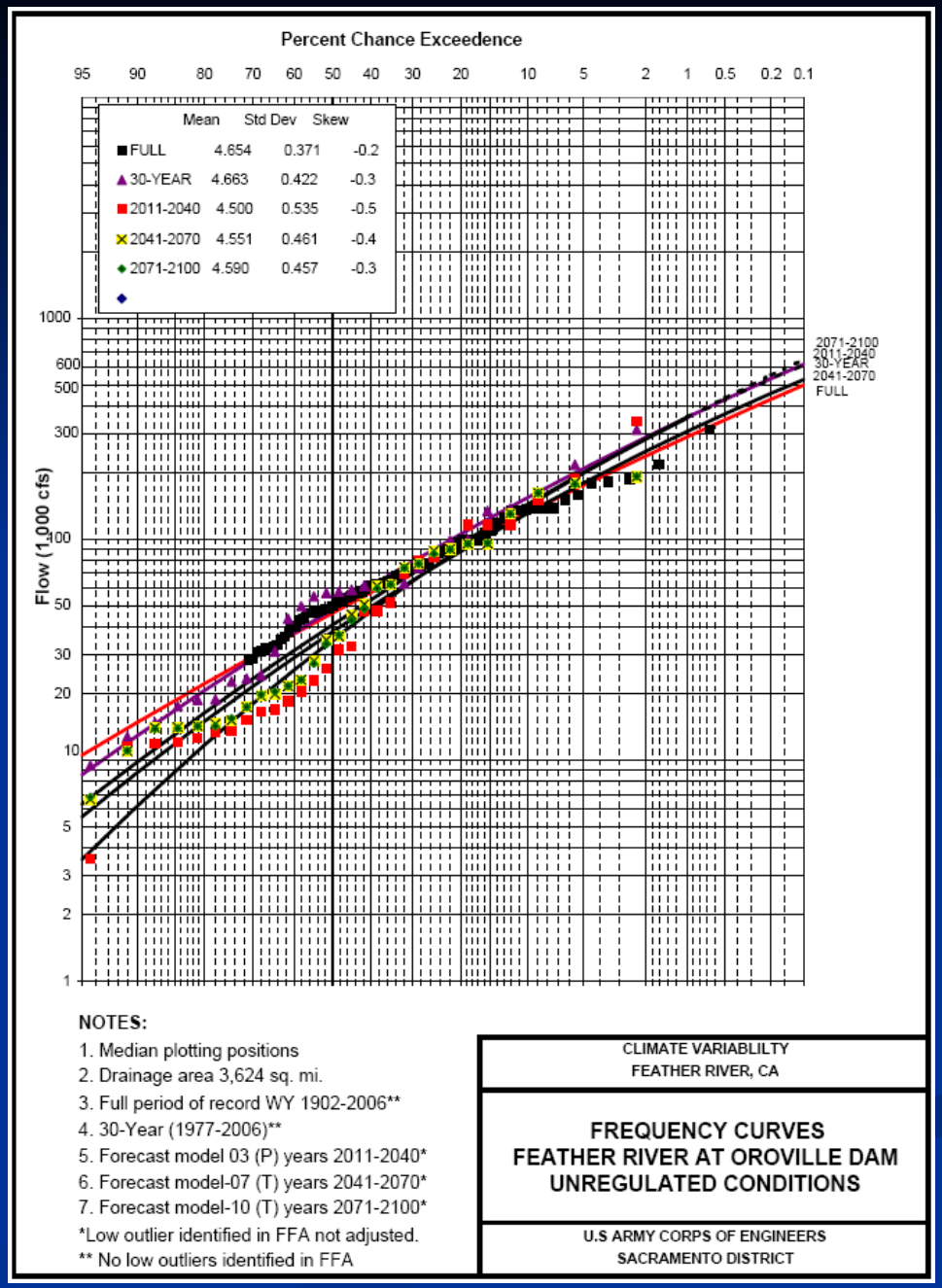
New Bullards

Data Set	*1% Inflow (1000 cfs)*
Full	95
Last 30 years	125
Model 07 (T) 2011-40	150
Model 07 (T) 2041-70	140
Model 07 (T) 2071-2100	150

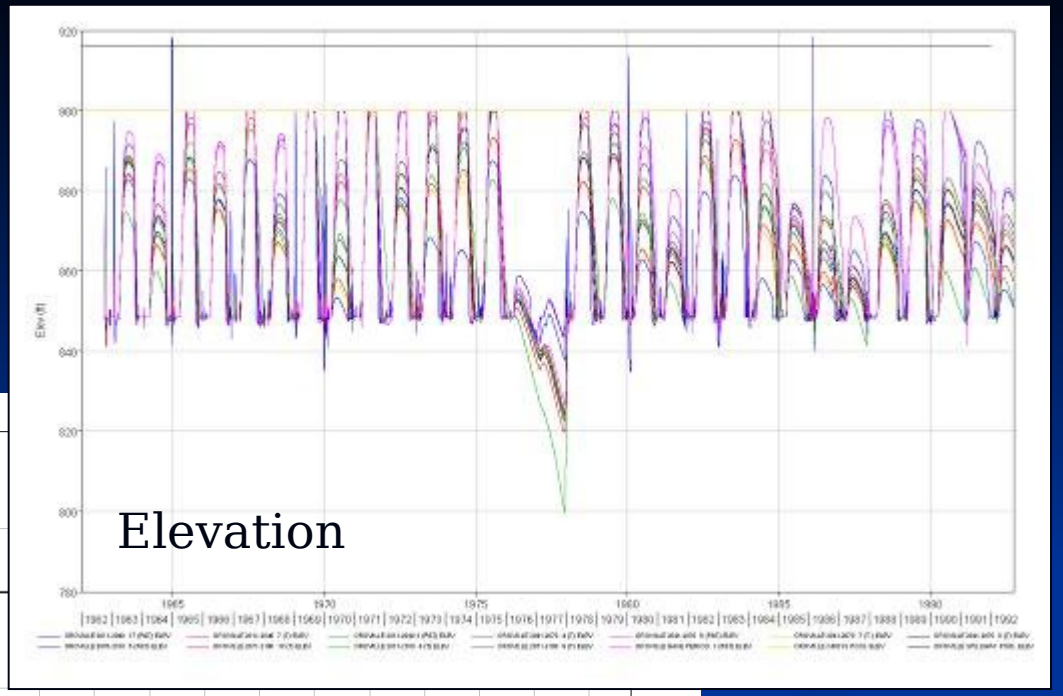


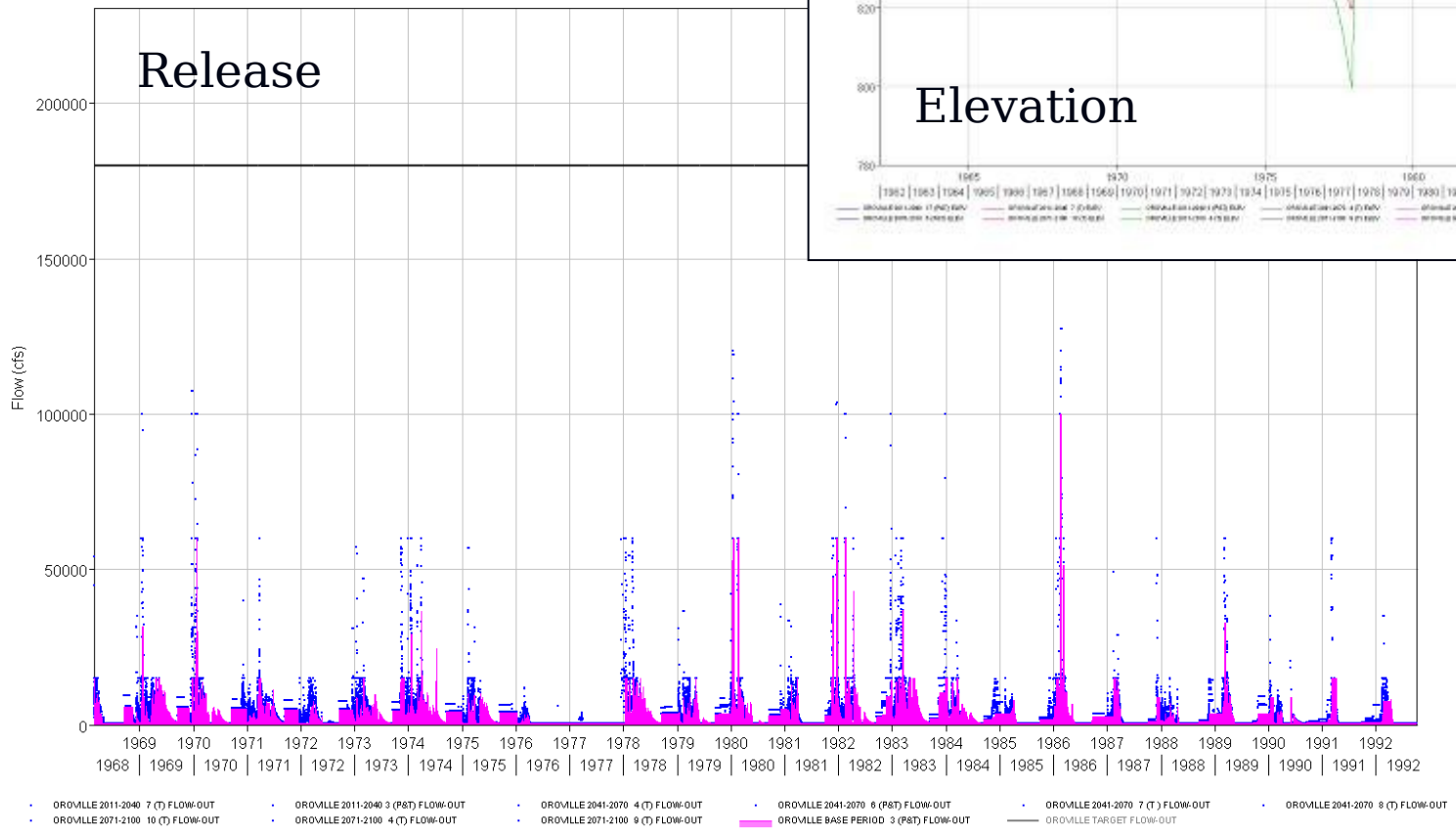
Oroville

Data Set	*1% Inflow 1000 cfs*
Full	300
Last 30 years	370
Model 03 (P) 2011-40	370
Model 07 (T) 2041-70	320
Model 10 (T) 2071-2100	370

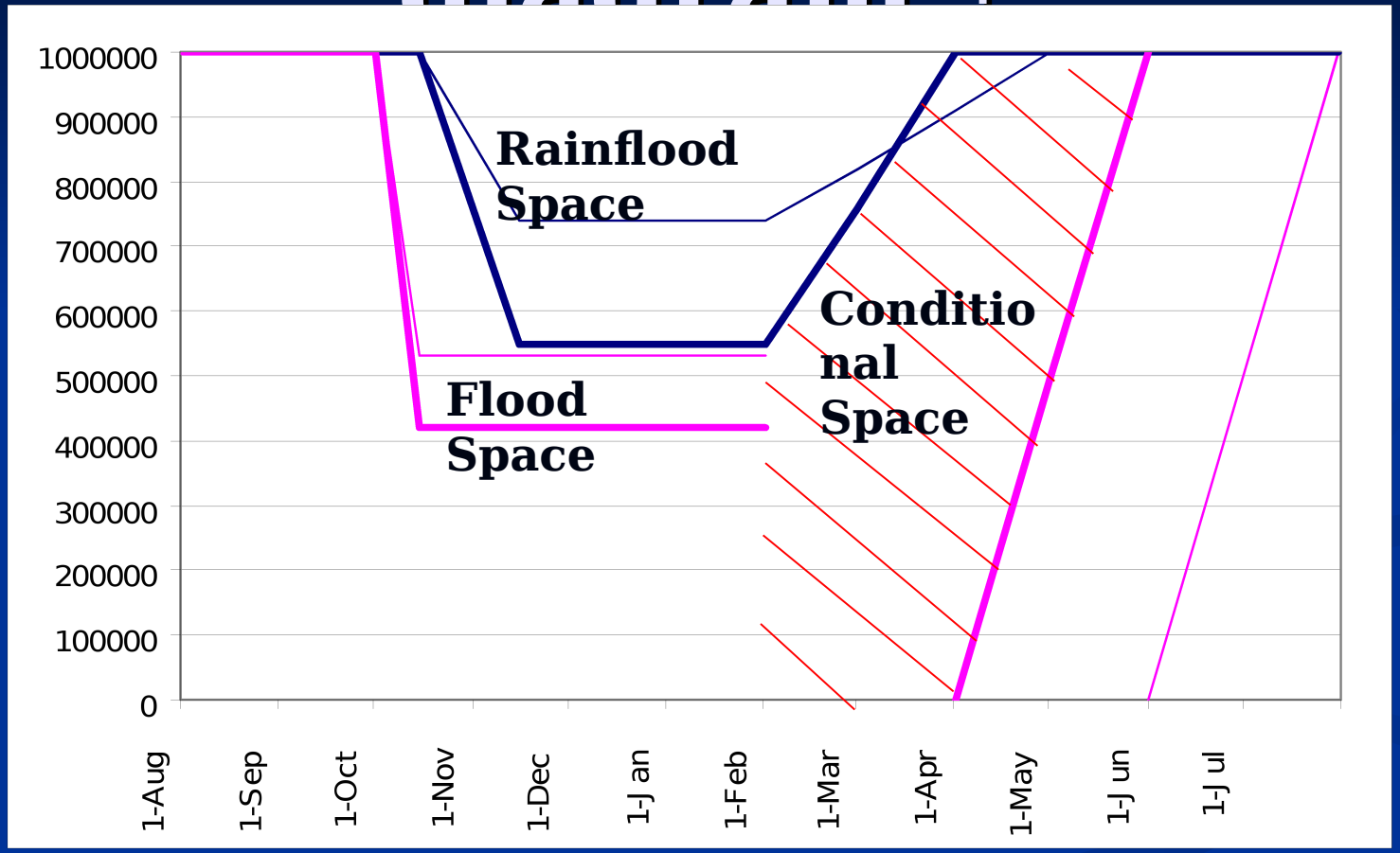

Percent Chance Exceedence
95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1
Mean Std Dev Skew
FULL 4.654 0.371 -0.2
30-YEAR 4.663 0.422 -0.3
2011-2040 4.500 0.535 -0.5
2041-2070 4.551 0.461 -0.4
2071-2100 4.590 0.457 -0.3
Flow (1,000 cfs)
1000 600 500 300 100 50 30 20 10 5 3 2 1
2071-2100
2011-2040
30-YEAR
2041-2070
FULL
NOTES:
1. Median plotting positions
2. Drainage area 3,624 sq. mi.
3. Full period of record WY 1902-2006**
4. 30-Year (1977-2006)**
5. Forecast model 03 (P) years 2011-2040*
6. Forecast model-07 (T) years 2041-2070*
7. Forecast model-10 (T) years 2071-2100*
*Low outlier identified in FFA not adjusted.
** No low outliers identified in FFA
CLIMATE VARIABLILTY
FEATHER RIVER, CA
FREQUENCY CURVES
FEATHER RIVER AT OROVILLE DAM
UNREGULATED CONDITIONS
U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

Oroville
operations under climate adjusted inflows




Release
Flow (cfs)
200000
150000
100000
50000
0
1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992
OROVILLE 2011-2040 7 (T) FLOW-OUT
OROVILLE 2011-2040 3 (P&T) FLOW-OUT
OROVILLE 2041-2070 4 (T) FLOW-OUT
OROVILLE 2041-2070 6 (P&T) FLOW-OUT
OROVILLE 2041-2070 7 (T) FLOW-OUT
OROVILLE 2041-2070 8 (T) FLOW-OUT
OROVILLE 2071-2100 10 (T) FLOW-OUT
OROVILLE 2071-2100 4 (T) FLOW-OUT
OROVILLE 2071-2100 9 (T) FLOW-OUT
OROVILLE BASE PERIOD 3 (P&T) FLOW-OUT
OROVILLE TARGET FLOW-OUT

Climate adjusted diagram ?



Jury still out – takes studies to resolve!

What next?

- Given
  - Climate change (mean is changing)
  - Climate variability (variance is increasing)
- Need better climate models at watershed scale
- Increased process-based, distributed analysis
- Less reliance on current statistical tools
- Move to adaptive rule curves?

Adaptive curves

- Current rule curves
  Storage = f(inflow, channel capacity, measured precip, forecast snowmelt, forecast demand)
- Potential curves
  Storage = f(above *plus* short-term weather forecast, mid-range climate forecast, advanced release, and ???)

Questions?